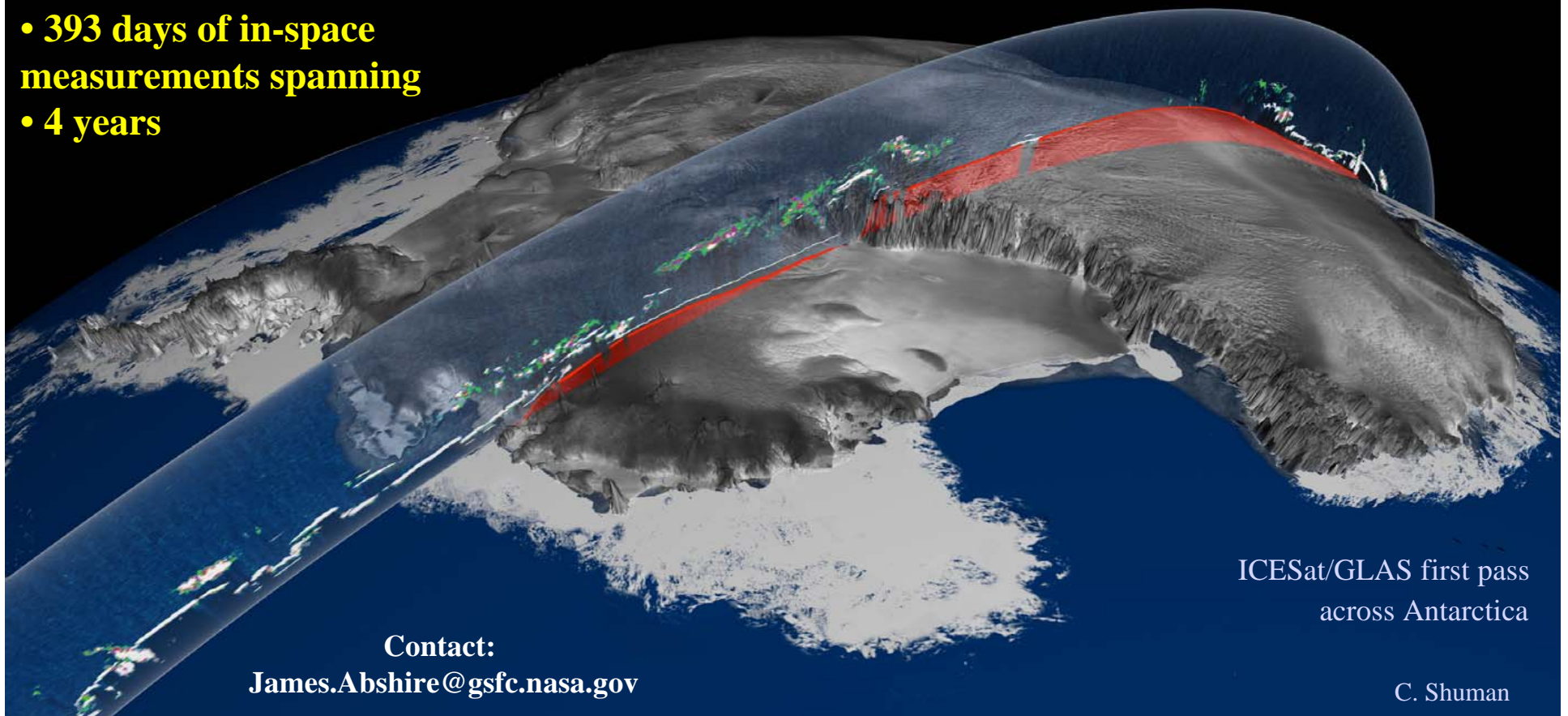


Geoscience Laser Altimeter System (GLAS) Update to Science Team

GLAS Instrument Team and GARB

February 22, 2007

- 1.3 Billion measurements
- 393 days of in-space measurements spanning
- 4 years



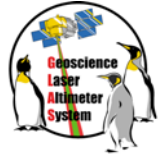
ICESat/GLAS first pass
across Antarctica

Contact:
James.Abshire@gsfc.nasa.gov

C. Shuman



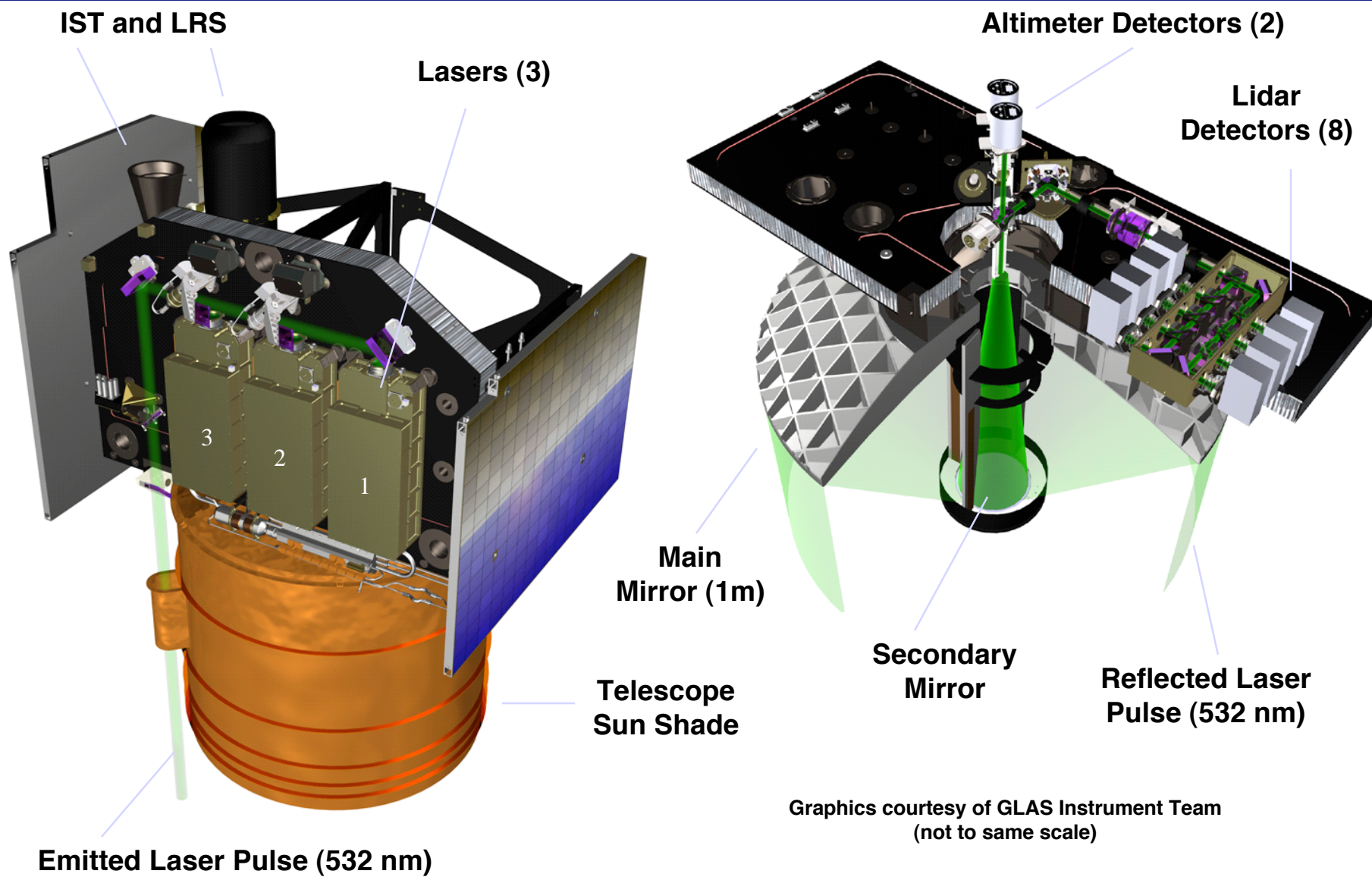
Laser Investigation (GARF) report



Outline:

- Energy History
- Laser 3 “fire acquisition” signal drop out risk & potential impact
- Recommendation for future Laser 3 operations
- Extended vacuum test of ETU laser - update
- “Lessons learned” activities
- Reminder of ongoing work:
 - Photodarkening study - will occur at UMD Chemistry Department
 - Manuscript on GLAS Laser design & pre-launch testing submitted to IEEE J.Q.E.
 - Extended vacuum test of GLAS ETU laser - documentation collected and is being consolidated

1. GLAS Instrument





Laser Operations History

4 Years & 11 Campaigns so far



Laser firings
through
11/27/06

Total:



Laser 3:



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003			L1							L2a		
2004			L2b			L2c				L3a		
2005			L3b			L3c				L3d		
2006			L3e			L3f				L3g		
2007		↑	L3h									
2008		Now										

Legend:
Flight Orientation

Airplane

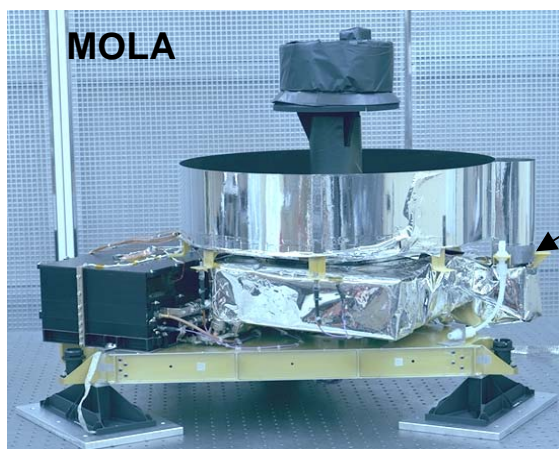
Sailboat



GLAS Flight Laser Firings (Millions) through 2/22/07

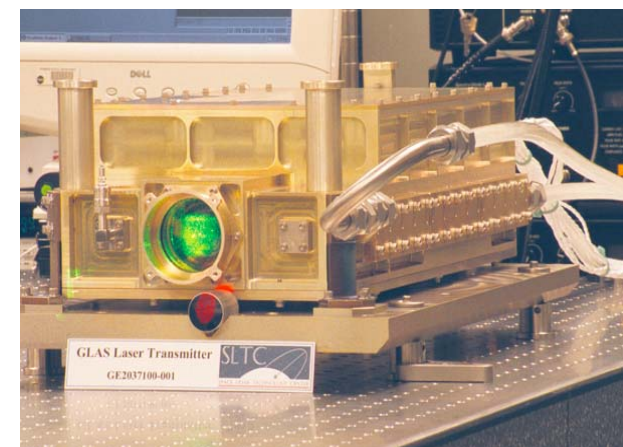


	Laser 1	Laser 2	Laser 3	TOTAL*	% of Mission Goal (3,784M)	Comparison to MOLA
Ground Testing*	158.8	140	128.8	427.6	11%	63% on orbit measurements
On-Orbit*	126.8	417.5	816*	1361	36%	202% of MOLA
TOTAL*	285.6	557.5	945	1788		
Status	Failed	Off	In Operation			



*Millions of shots

** -MOLA Laser Total
(previous record):
= 673 million
space laser firings



GLAS Lasers - pump diode parts issue

GLAS Laser Heritage and Testing

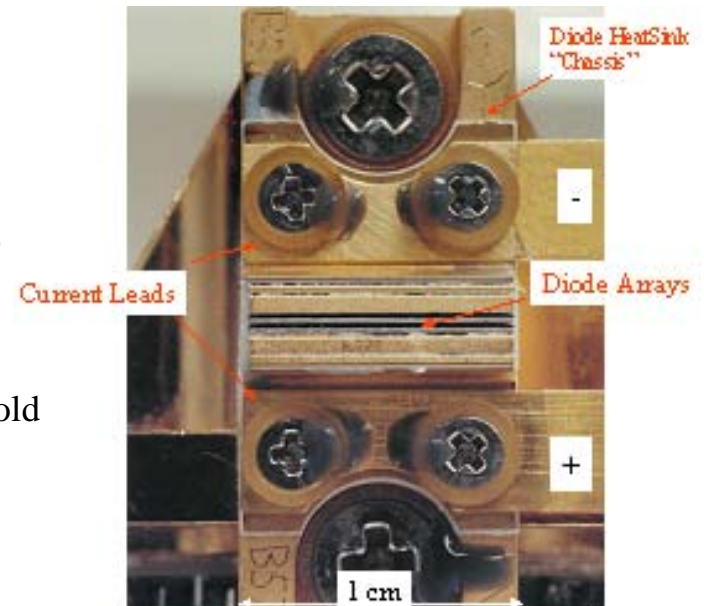
- GLAS pump diodes & osc stage tested for 3-6 billion pulses
- Pump arrays were selected versions of commercial parts
- Used de-rated (less drive current than commercial spec)
- Gold-in-die defect was latent & did not surface in life- or pre-launch tests

GLAS Anomaly Review:

- Laser 1 failure was from a parts problem
 - vendor's use of indium in diode pump array assembly, leading to gold erosion & bond wire failure
- Laser 2 energy decay likely from slow contamination

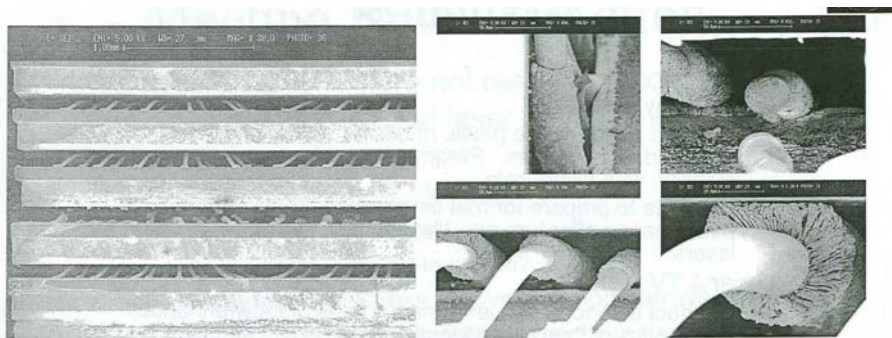
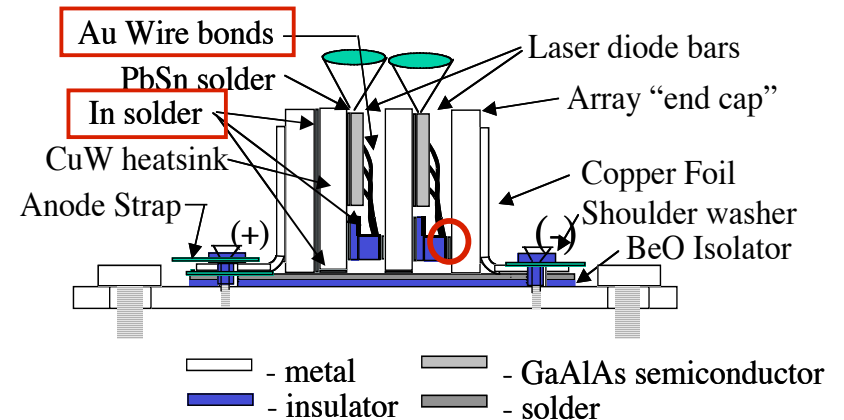
Programmatic:

- GLAS was Class C instrument with Grade 3 parts program
- One vendor for an expensive & surprisingly complex part

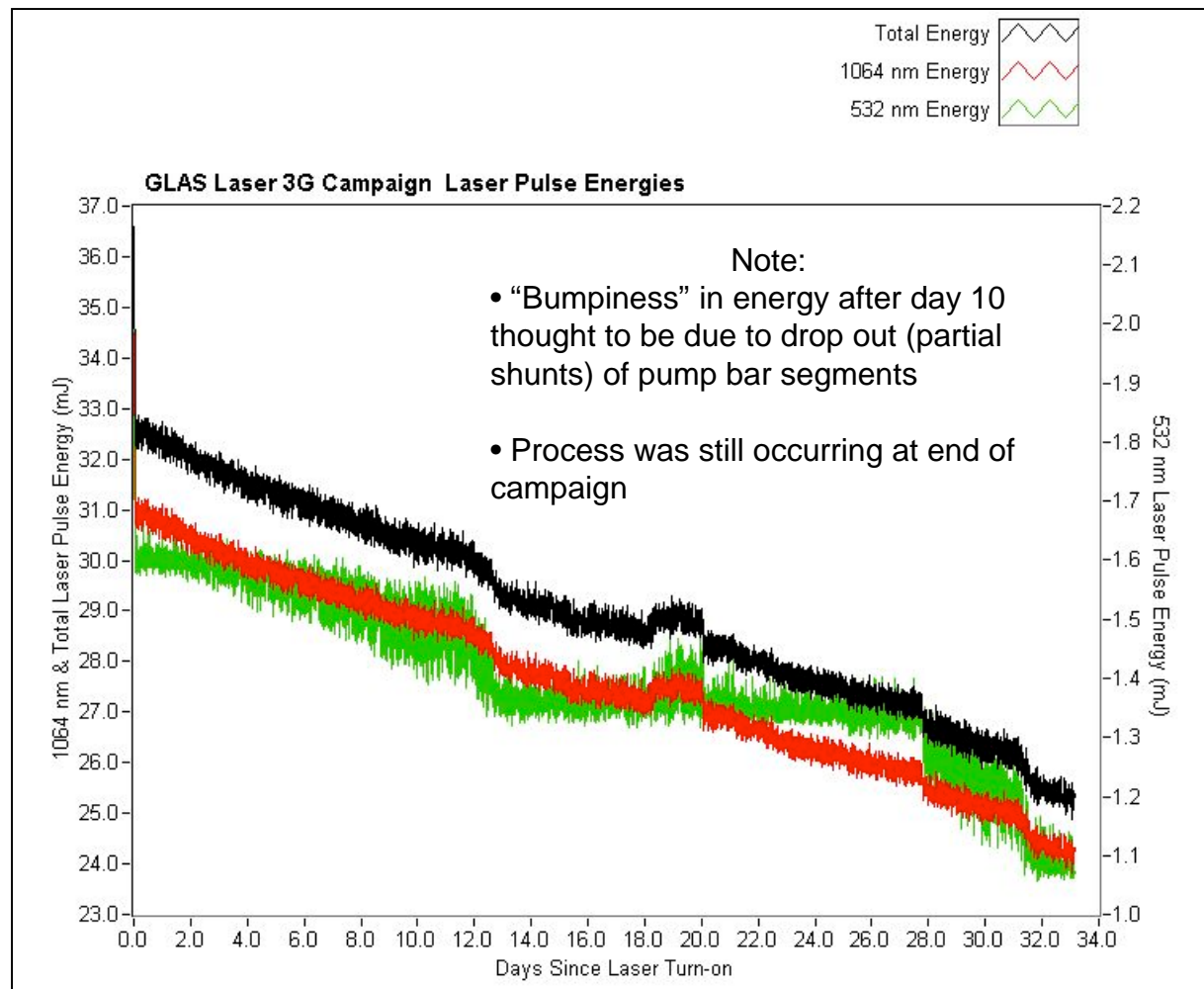


SDL 100W diode array (G2)

Side sketch

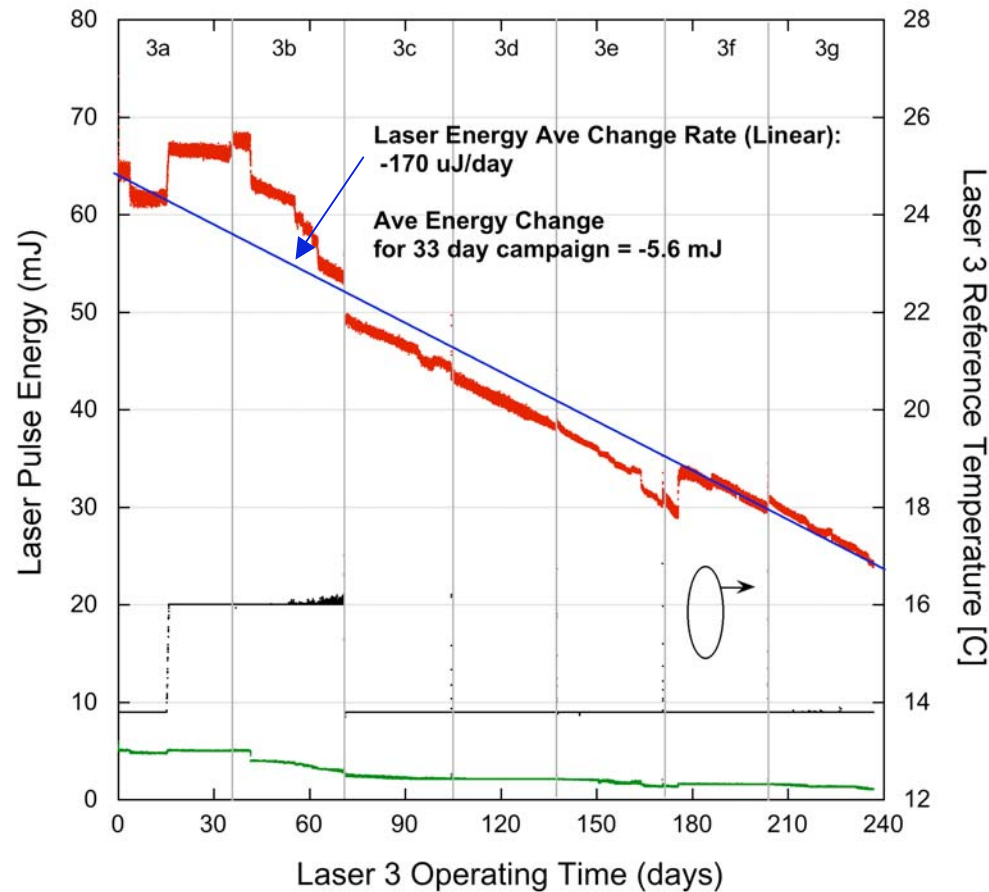


Laser 3G Campaign Energy History





GLAS Laser 3 - Average Energy Trend through end of L3g campaign



Simple linear extrapolation of 1064 nm energy:

- 7 campaigns to date
- 1064 nm energy change = - 41.5 mJ
- Ave energy change = -5.6mJ/campaign
- Presently at 23.5 mJ

Reminder - “Fire Acquisition” Loss Risk for Laser 3

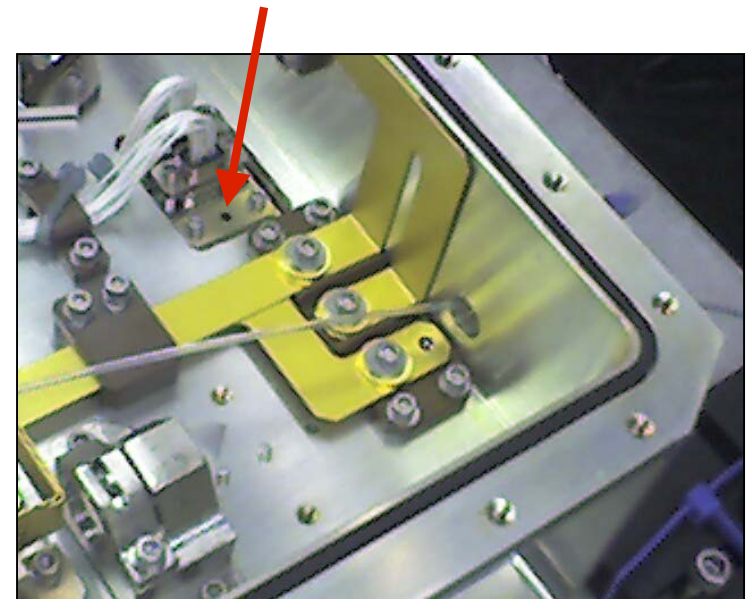
There is an internal optical detector inside the laser box used to determine when the oscillator has triggered (ie Q-switched) and to turn off the electrical drive pulse to the laser diodes when it occurs.

It is called the "fire acq" detector. It views scattered 1064 nm laser light inside the laser box.

Normally the diode pump electrical drive pulse width is about 200 usec. This pump diode pulse width is the laser fire delay - ie the time from when laser is commanded to fire to that when it actually emits the laser pulse.

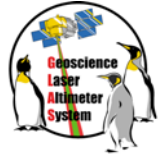
When the 1064 nm energy inside the laser box decays far enough (< 10 mJ), the fire acq signal will not cross an internal threshold, and the electrical pump pulse will stay on.

The GARB isn't certain of the exact fire acq threshold - it is possible it is < 5 mJ





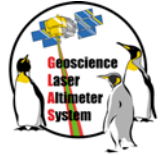
Laser 3 - Risk from loss of “Fire Acquisition” Signal



- At some point, for output energies <10 mJ, Laser 3 is expected to lose its “fire acquisition” signal - an internal trigger signal inside the laser.
- The expected consequence of this are:
 - The laser drive pulse to the diodes will go from 200 to 244 usec. The laser will emit a pulses, but the pumps diodes will stay on longer. This won't break the laser, but it may cause an error in selecting the start pulse for the altimetry. The altimetry electronics may miss the time of the start pulse.
 - The current draw from the laser will increase about ~ 1 A (30W) (ie from ~ 100 to 130 W). The extra 30W needed by the laser will stress the spacecraft's power system, particularly if it occurs during eclipse, when the spacecraft is drawing power only from its batteries.
 - As expected, with the worst-case predicted end-of-eclipse battery voltage at the laser could be from 22.7 to 23V. The lasers low voltage cut-off is 23.1V \Rightarrow a problem. If the voltage falls to this point, the laser will stop and go into “restart mode”, which takes severla hundred seconds. This power cycling will be extra stress on the laser, particularly on its pump diodes.
 - If, for worst case conditions, the GLAS power can be reduced by 45W, there should be ~ 0.15 V or more of margin. There are several other options that may give us extra voltage.
 - Other possibilities might be to not operate during the worst case conditions for spacecraft power, (ie early in the spring campaign), or shift it to a later time.



Recommended Laser 3 Operating Plan



- The GARB recommends operating Laser 3 at constant temperature, but with ramp-type temperature increases at the end of the next few campaigns, until the laser reference temperature reaches ~29C.
 - At end of each of next 3 science campaigns, raise laser temp ~5C at constant rate of ~3C/day
 - Each Laser temp increase of 5C are expected to increase 1064 nm laser energy by 5-7 mJ.
 - At the end of each temperature raising period, dwell at new temp TBD orbits (enough for laser to stabilize).
 - The maximum laser energy is expected at ~29C. Dwell at ~29C for all campaigns once this is reached.
 - Each temp change is expected to largely compensate for laser energy loss of the campaign immediately preceding, assuming an average per campaign energy loss. That is, if Laser 3 follows its past behavior, its 1064 nm energy is not expected to drop below its present energy of ~25 mJ/pulse until during campaign L3k and afterwards.

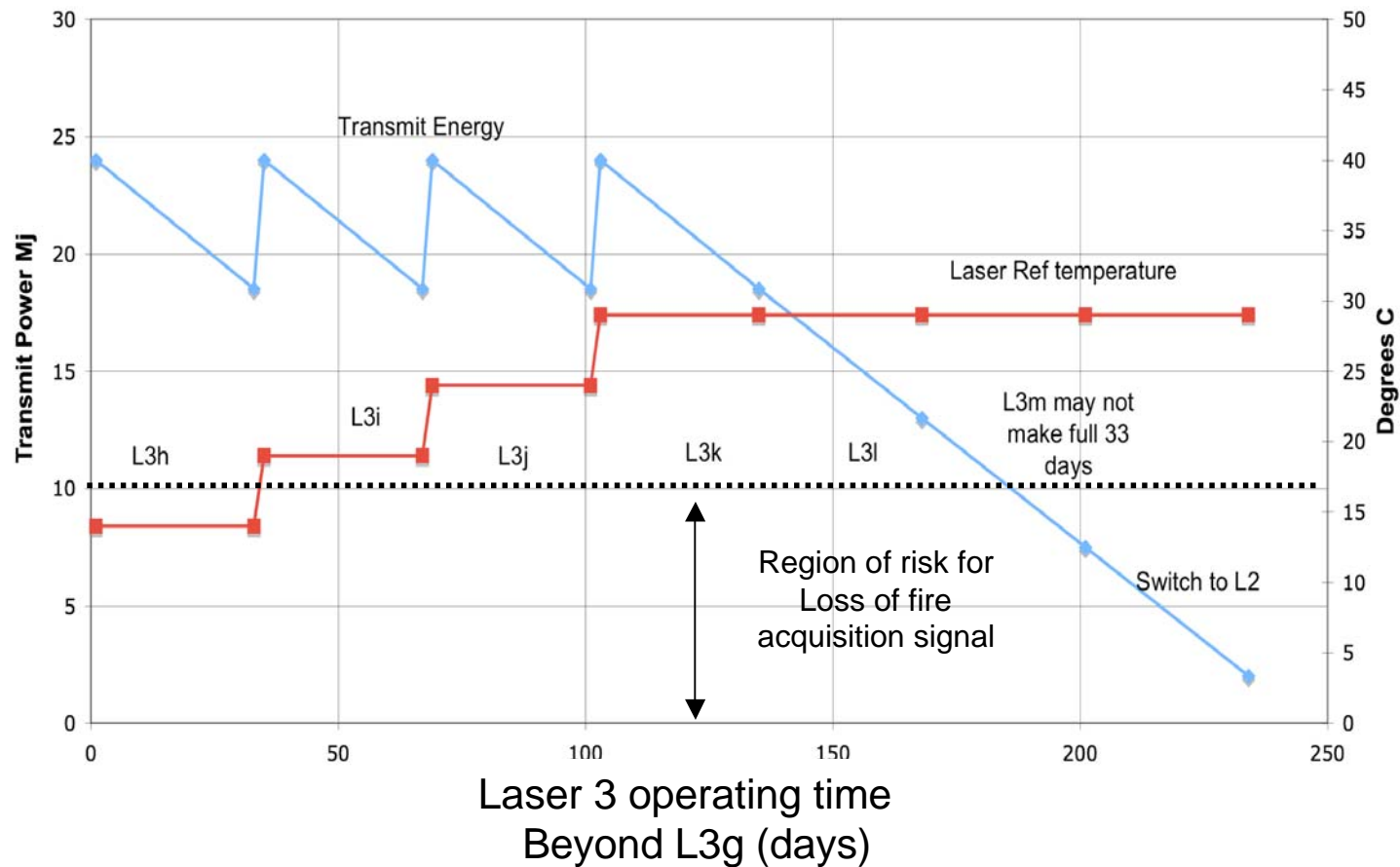


Extrapolated Laser 3 Energy Trend using recommended Temperature plan



(based on extrapolating past trends)

~ 5 more campaigns with L3





Laser 3 Operating Recommendations - 1/3



Laser 3 Operation and Temperature plan

Recommendations from the GARB

2/14/07

A. Overview/Abstract:

The GARB recommends operating Laser 3 at constant temperature, but with ramp-type temperature increases at the end of the next few campaigns, until the laser reference temperature reaches ~29C.

B. Background

Laser 3 has been used successfully in orbit for 7 science campaigns so far. Since its early operation, the Laser 3 temperature has been set to about 14C. The laser's pulse energy at last use was about 30 mJ, and it has lost roughly 5-6 mJ output pulse energy during each operational campaign. The laser's energy decline is thought to be a consequence of the gradual loss of output power from its diode pump arrays with use.

The most recent laser energy, coupled with its trend, have highlighted some issues and concerns. With less transmitted energy, an increasing percentage of echo pulses fall below the receiver's detection threshold in cloudy polar regions. The smaller echo pulse energies causes more pulses in cloudy areas to be missed. The atmospheric lidar measurements made with less laser energy will have lower SNR and quality.

There is also an anticipated operational risk to Laser 3 when its output energy falls < 10 mJ. At some energy below 10 mJ, there is a risk that an internal sensor inside the laser will not trigger - that is there will be a loss of the lasers "fire acquisition" signal. This sensor is usually normally used to stop the pumping pulse to the laser. Calculations and tests show this "loss of fire acquisition" will likely occur at a laser energy < 10 mJ. However the fidelity of these did not allow a precise determination of the threshold energy for triggering.

When the fire acquisition signal is lost in Laser 3, our expectation is that it will cause an increased laser current draw, a change in the start pulse timing relative to the command to fire the laser. The increased current draw could cause a voltage drop and some undesired laser power cycling of the laser, if this occurs during an eclipse part of the orbit, which the spacecraft battery voltage is low. Although these are not expected to break the laser, some of these occurring together would likely disrupt a science campaign. Any unneeded laser power cycling would likely cause additional and unwanted stress to the solder joints and bond wires inside the laser's diode pump array parts. These could shorten the remaining laser lifetime.



Laser 3 Operating Recommendations - 2/3



Although Laser 2's output energy has declined to below 10 mJ, it is not thought to not have this risk. This is because the cause of the Laser 2 reduced output energy is thought to be an optical attenuation layer which formed and grew inside the laser. This is thought to be present inside the laser near the output beam and beyond the internal sensor. Due to this, the internal sensor in Laser 2 is thought to be seeing much higher laser energy, at was not to be at risk from a loss of fire acquisition event.

Due to these known and potential consequences to Laser 3, the GARB plan is to prevent the loss of fire acquisition event for Laser 3 as long as possible, while utilizing the lessons we have learned for extending the GLAS laser lifetimes.

The Laser 3's output energy can be increased by raising its reference temperature. This shifts the wavelengths of the pump diodes emission to better match the absorption band of the laser's ND:YAG crystals. Ground testing showed that the maximum laser energy occurred at $\sim 29^{\circ}\text{C}$. Operating the laser at warmer temperatures will increase the pulse energy and will maximize the time until the loss of fire acquisition signal event. This also allows more operating time at higher energies. Higher energies allow higher percentage measurements through clouds, compared to staying at the present temperature.

The GARB plan, summarized below, raises the temperatures, using a ramps of 5°C , at the end of each of the next 3 campaigns, until it reaches $\sim 29^{\circ}\text{C}$. The proposed temperature raise rate ($3^{\circ}\text{C}/\text{day}$) has been used successfully on orbit. There is a benefit in laser monitoring by stopping and re-starting the laser at the same temperature, which this plan allows. The plan also keeps the laser temperature constant for the science portions of the campaigns, in order to minimize disturbances to precision pointing determination. Some additional rationale for this plan is summarized in E. below.

C. Approach:

1. At end of each of next 3 science campaigns, raise laser temp $\sim 5^{\circ}\text{C}$ at constant rate of $\sim 3^{\circ}\text{C}/\text{day}$, as in the Table in D. below.
2. Each Laser temp increase of 5°C are expected to increase 1064 nm laser energy by 5-7 mJ
3. At the end of each temperature raising period, dwell at new temp TBD orbits (enough for laser to stabilize).
4. The maximum laser energy is expected at $\sim 29^{\circ}\text{C}$. Dwell at $\sim 29^{\circ}\text{C}$ for all campaigns once this is reached,
5. Each temp change is expected to largely compensate for laser energy loss of the campaign immediately preceding, assuming an average per campaign energy loss. That is, if Laser 3 follows its past behavior, its 1064 nm energy is not expected to drop below its present energy of ~ 25 mJ/pulse until during campaign L3k and afterwards.



Laser 3 Operating Recommendations - 3/3



D. Summary- Nominal Laser 3 temperature operation table:

Campaign	Op temp* (C)	End temp** (C)
L3h	13.8	18.8
L3i	18.8	23.8
L3j	23.8	28.8
L3k & beyond	28.8	28.8

* - during science ops

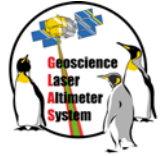
** temp raise started at the end of science campaign

E. Additional Comments:

1. - The number of degrees in each temperature increase could be adjusted some, if needed, to fine tune this plan for observed changes in laser energy decay rates, or for more or less energy loss due to energy step down (bar drop) events, actual performance, etc.
2. This plan was developed considering experience which showed that there is a science benefit to keeping laser temp constant during science campaigns.
3. Incremental temp changes are closer to the laser on-orbit history, and are considered to have less risk than larger making larger temp changes.
4. There is a benefit to monitoring the laser health in starting and ending laser campaigns at same temperature.
5. The temperature increases might increase the 532 nm energy. However the potential increase is uncertain due to uncertainties about underlying causes of lower 532 nm energy presently in Laser 3.
6. The risk of increased photodarkening with increased 532nm energy is thought to be small, due to the laser's >3 years in space vacuum. The residual level of contamination remaining in Laser 3 now is expected to be much lower than those in Lasers 1 & 2 when they were operated.
7. The daily laser energy loss rates will likely increase some with increase laser energy, perhaps in proportion to energy.
8. With the pump diode parts issue present in all lasers, there is still some residual risk of a sudden laser failure due to bond wire failure and/or a bar-blowout events.



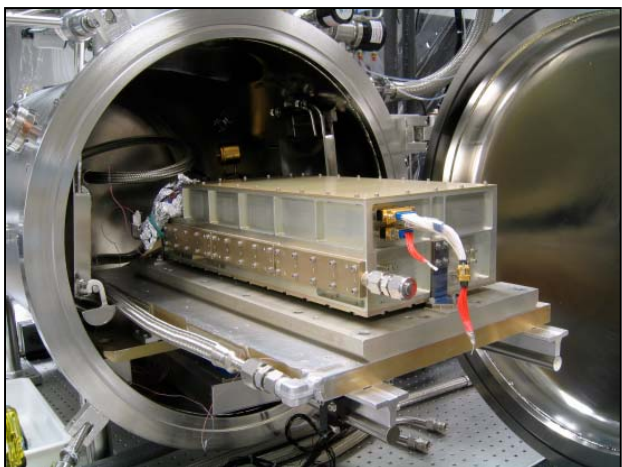
GLAS ETU Laser Vacuum Test Post test inspection Update



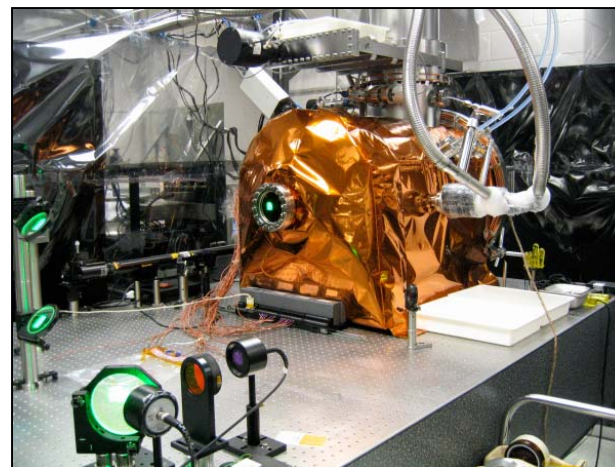
2/21/07

- The GARB tested the GLAS ETU laser in vacuum for ~44 days in late 2004
 - Little evidence of photodarkening was seen
 - The test ended after a chiller stopped, which caused the laser temp to spike
 - When the chiller was restarted, it caused a rapid cooling (thermal shock) of the laser
 - After this rapid temp change the laser was stopped.
 - It would not restart
-
- The GARB undertook surgery on the ETU laser to remove and inspect the various optical elements
 - The laser interior was found to be very clean, and little stacking compound was found.
 - This is one piece of evidence which points to the staking compound as the source of trace contamination for on-orbit photo-darkening
 - Additional ETU laser disassembly and examination has occurred recently
 - The GARB is presently examining the most recent findings, and will fold it into its ETU analysis

Photos of ETU Laser vacuum test



Laser inserted in the chamber

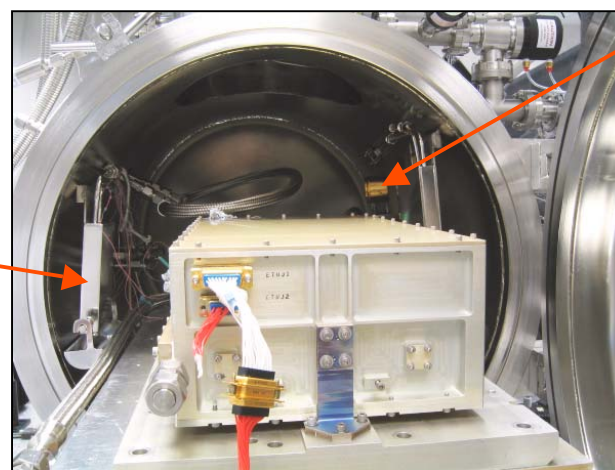


Laser firing in chamber



Note IR beam as seen
by the Digital Camera

Energy Detectors



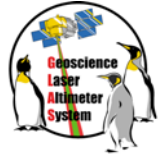
Scavenger Plate

CQCM Heat sink

Chamber



GLAS “Lessons Learned” Activity



- Jim Abshire & GLAS Instrument Science Team are leading an activity to capture & document the “lessons learned” from GLAS
- Is important to document these now, so they can be considered in future plans
- Includes lessons we have learned (or are learning) from:
 - The GLAS lasers
 - Other parts of GLAS instrument - its design & measurement approach
- He will be soliciting inputs from team members for this
 - Particularly those who helped determine GLAS on-orbit measurement performance
- A report will be prepared and submitted to GSFC & HQ management
 - The schedule is being developed
 - Will present its status at the next team meeting
- Thanks in advance for your participation and support.